**BELLCOMM, INC.**

SUBJECT: First Lunar Landing Mission Description, MSF Review Presentation, November 22, 1966 Case 310

DATE: February 28, 1967

FROM: D. R. Anselmo
W. D. Kinney

## MEMORANDUM FOR FILE

On November 22, 1966 a presentation was given at the MSF Program Review on the subject of "Launch Flexibility". It was concerned with the specific flexibility required of the Apollo System for the first lunar landing mission. As a part of this presentation a brief review was given of the general nature of a "typical" sequence of mission opportunities. Attached are prints of the viewgraphs used for this part of the presentation together with explanatory material. (These viewgraphs without detailed descriptive material are also part of an earlier Memorandum for File, "System Hold and Recycle Capability for the First Lunar Landing Mission," by R. L. Wagner, December 14, 1966.) A few additional figures have been included for completeness.

The general coverage of the attached material includes comments on the strategy for selecting lunar landing site locations, based on mission constraints and operational requirements, and a brief description of the family of missions occurring during 1968 for an assumed set of landing sites.

D R Anselmo

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Attachment

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## Viewgraph 1

### Schematic Representation of a Possible Distribution of Apollo Landing Sites

A distribution of lunar landing sites such as that shown in this viewgraph can provide both fuel economy and mission flexibility. This viewgraph illustrates a string of northern sites (ABC) and southern sites (XYZ) spread across the Apollo landing zone.

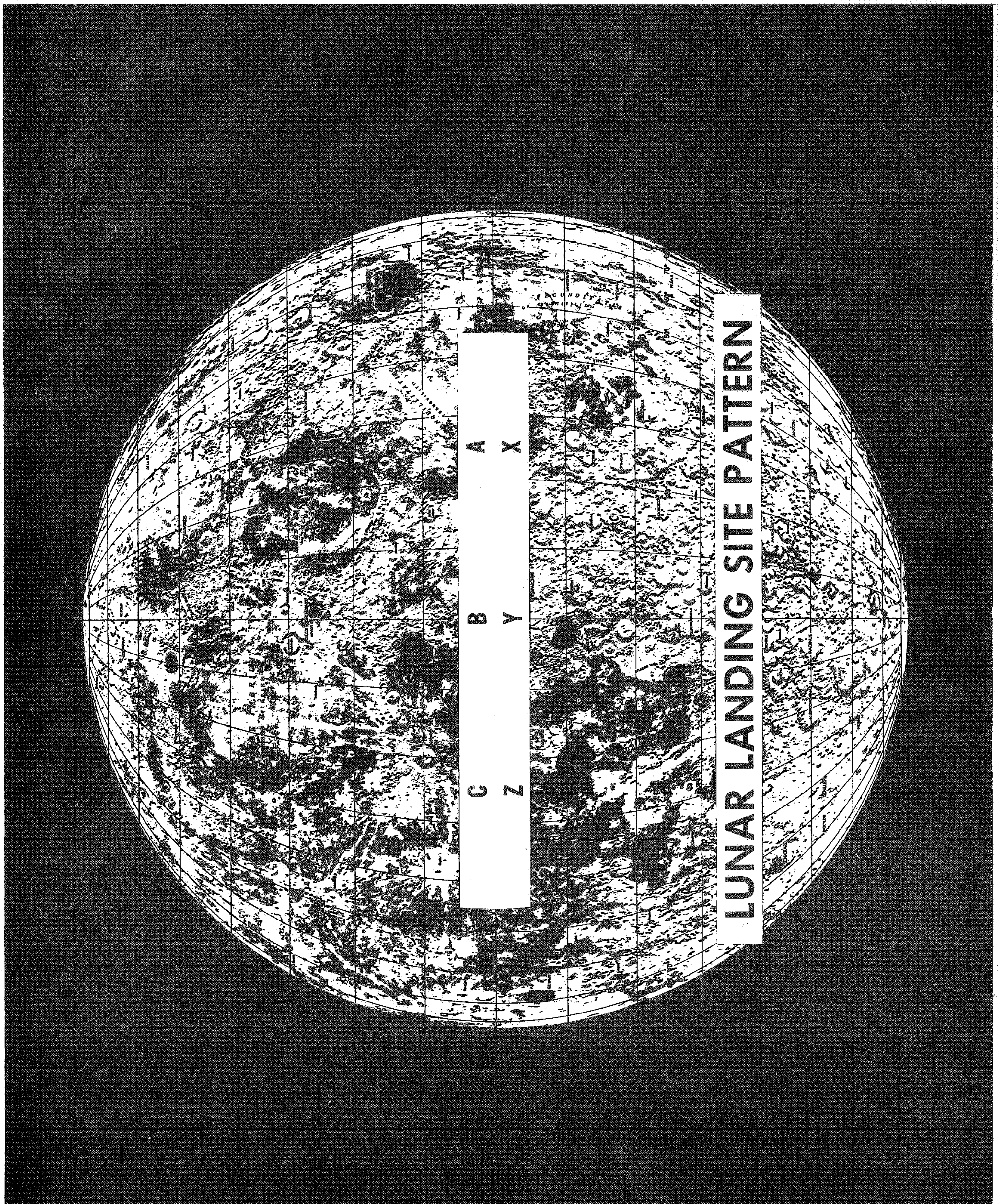
The sites are spaced longitudinally in order to provide multiple launch opportunities each month while meeting the required lighting conditions (sun elevation between 7° and 20°) at lunar landing. The sites are spaced latitudinally in order to provide spacecraft fuel economy while maintaining control over which of the two daily launch opportunities is used. (This is discussed more fully with the next three viewgraphs.) It is illustrated that for fuel economy one string of sites would be used for part of the year and the other string for the remainder of the year.

The non-uniform nature of the lunar surface will undoubtedly cause an irregular distribution of sites. Nevertheless a distribution exhibiting this general pattern can provide the desired characteristics.

# ATTACHMENT

## Introduction

The first lunar landing mission is expected to employ a free return trajectory and a lunar landing site which is selected in accordance with the launch date. The coupling between landing site and launch date is the subject of the first four viewgraphs. With the aid of these figures, general considerations which accompany the selection of an array of landing sites are discussed from the viewpoint of meeting the lighting constraint at LM landing and of enhancing spacecraft performance while at the same time providing for a reasonably spaced sequence of launch opportunities.

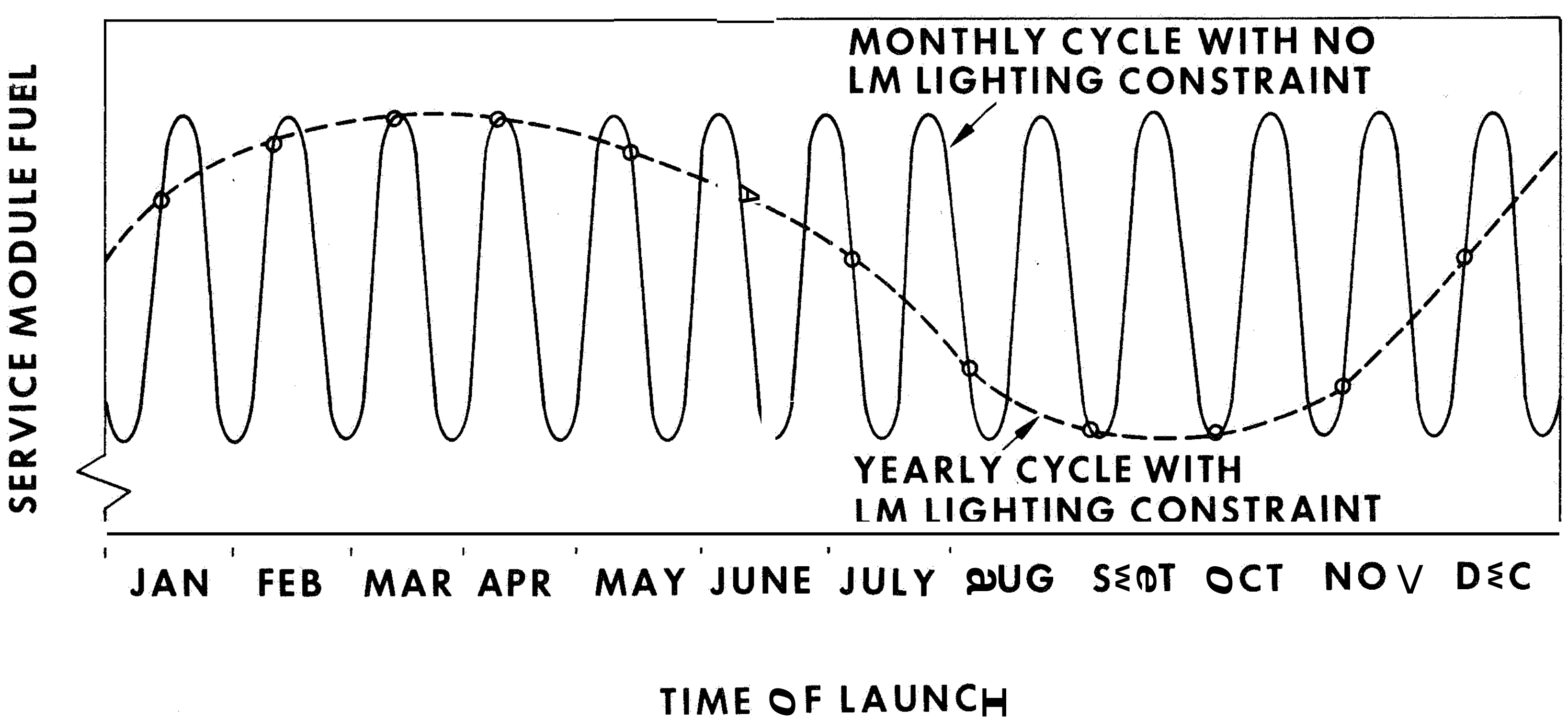

C B A
Z Y X
LUNAR LANDING SITE PATTERN

Viewgraph 2

SM Fuel Variation with Time - One Injection Type (Atlantic or Pacific)

This viewgraph illustrates the variation of Service Module fuel costs through a year for a given landing site and injection type. If lunar lighting at the time of landing is ignored, a mission is possible every day. The fuel costs would then vary cyclically through the year with a period equal to the period of revolution of the Moon around the Earth. The lighting requirements at lunar landing, however, permit a landing at a particular site only one day a month. Since the lunar lighting period (i.e., from new moon to new moon) is approximately two days longer than the period of the Moon's revolution, the Moon is at a slightly different point in its orbit at the time the lighting constraint is met in successive months. This causes the fuel requirements to vary as illustrated by the dashed curve in the figure.

# MONTHLY AND YEARLY SERVICE MODULE FUEL CYCLES



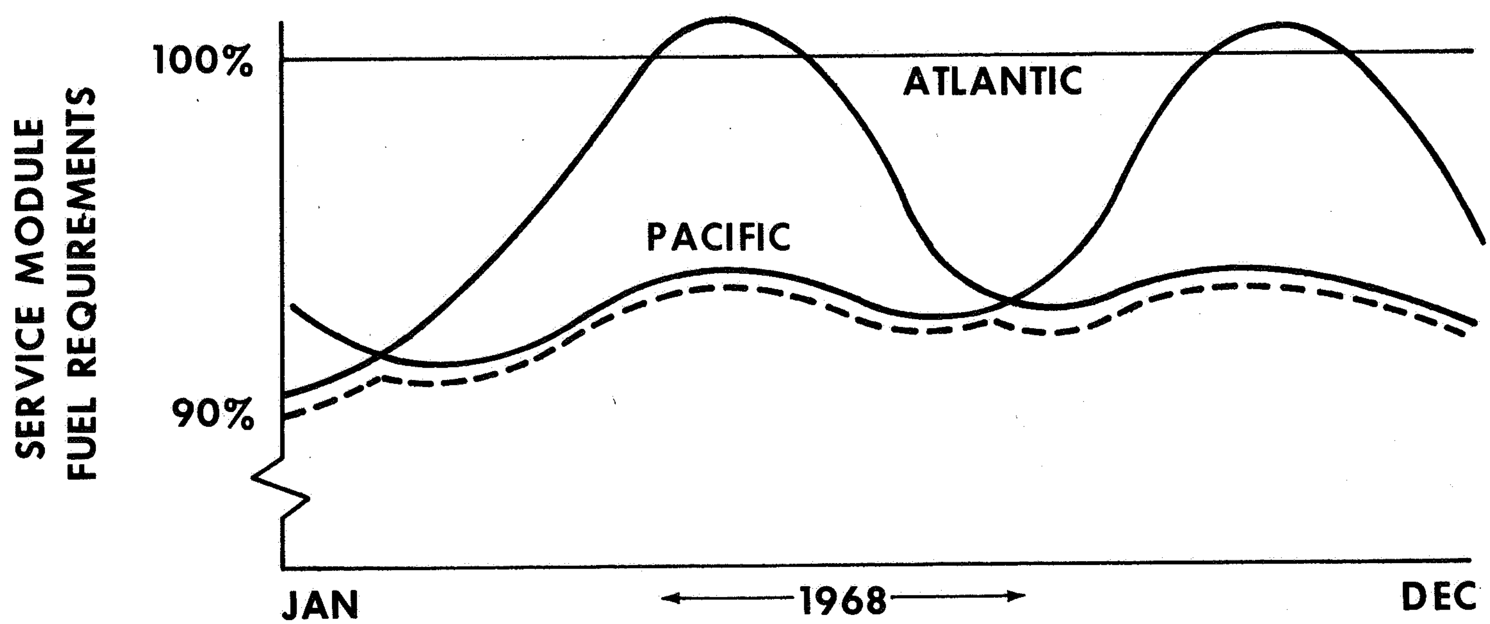
## Viewgraph 3

### SM Fuel Variation with Time - Both Injection Types

This viewgraph illustrates the yearly behavior of Service Module fuel requirements to achieve a particular lunar landing site with a specified injection type. The figure suggests a strategy for controlling fuel costs: namely, that of utilizing both Atlantic and Pacific windows. The requirements are then as illustrated by the broken line.

# TYPICAL FUEL/TIME CURVES FOR LUNAR EQUATORIAL SITE

LOWEST AVERAGE FUEL REQUIREMENTS IF BOTH ATLANTIC AND PACIFIC WINDOWS ARE UTILIZED (LONGITUDE = 45° W)



Viewgraph 4

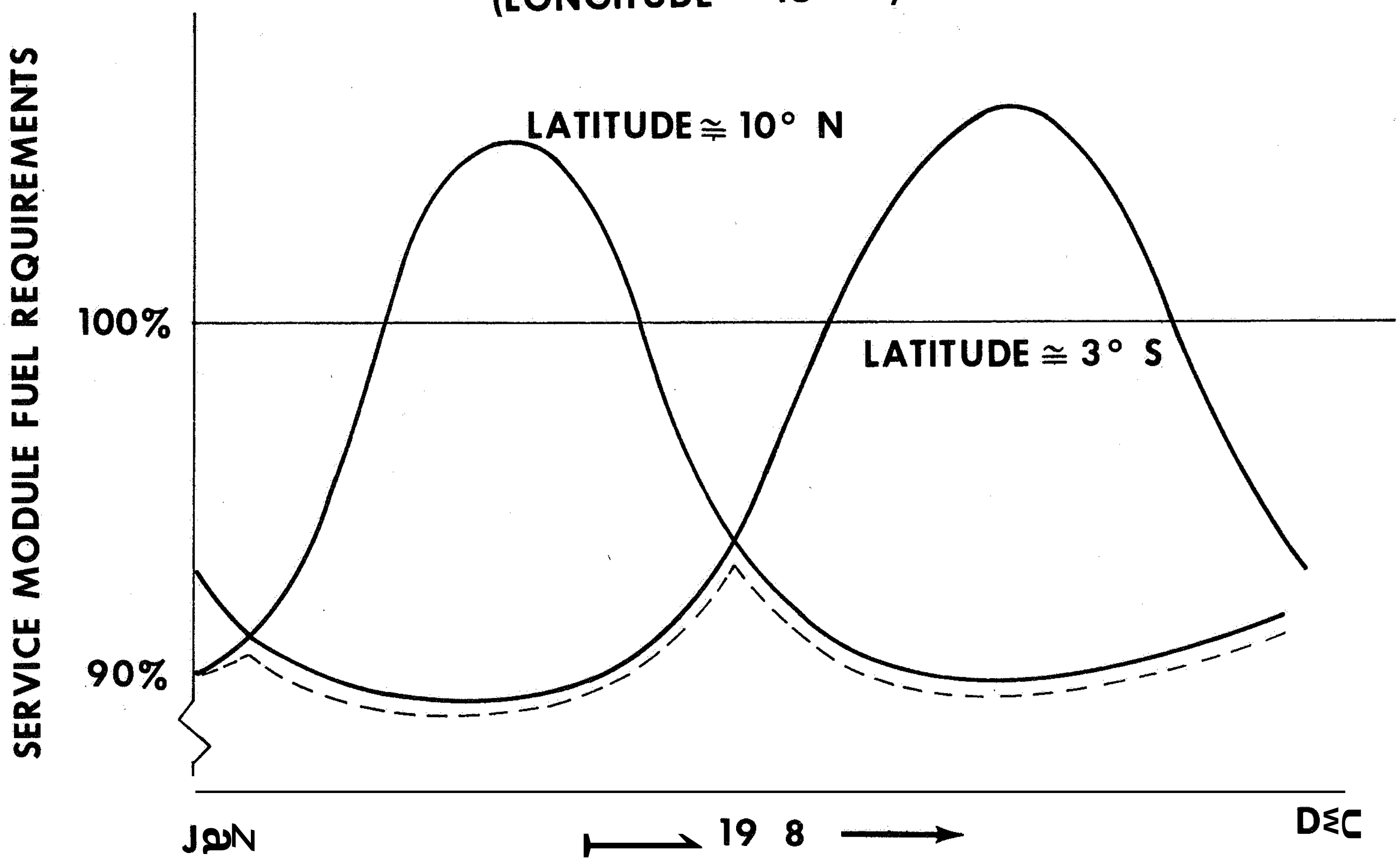
SM Fuel Variation with Time - Two Lunar Landing Sites

This viewgraph illustrates another possible technique of controlling fuel requirements: that of utilizing a fixed injection type and a pair of (north and south) landing sites. Here it is seen that when the landing site is moved in latitude, control of fuel requirements equivalent to changing injection types can be obtained. This effect is more pronounced for landing sites in the western sector of the Apollo landing zone.

With this strategy the choice of injection type is available to control other desirable mission parameters. For this study the Pacific injection opportunity was used throughout because it almost always produces daylight launch conditions. The ability to realistically adhere to this preference will depend upon whether or not acceptable sites can be found sufficiently far north of the equator in the western half of the moon. (Recent indications from Orbiter II are that acceptable landing sites will be hard to find in this location).

# TYPICAL FUEL/TIME CURVES FOR PACIFIC WINDOW WHEN LANDING SITE CAN BE MOVED LATITUDINALLY TO MINIMIZE FUEL

(LONGITUDE = 45° W)



Viewgraph 5

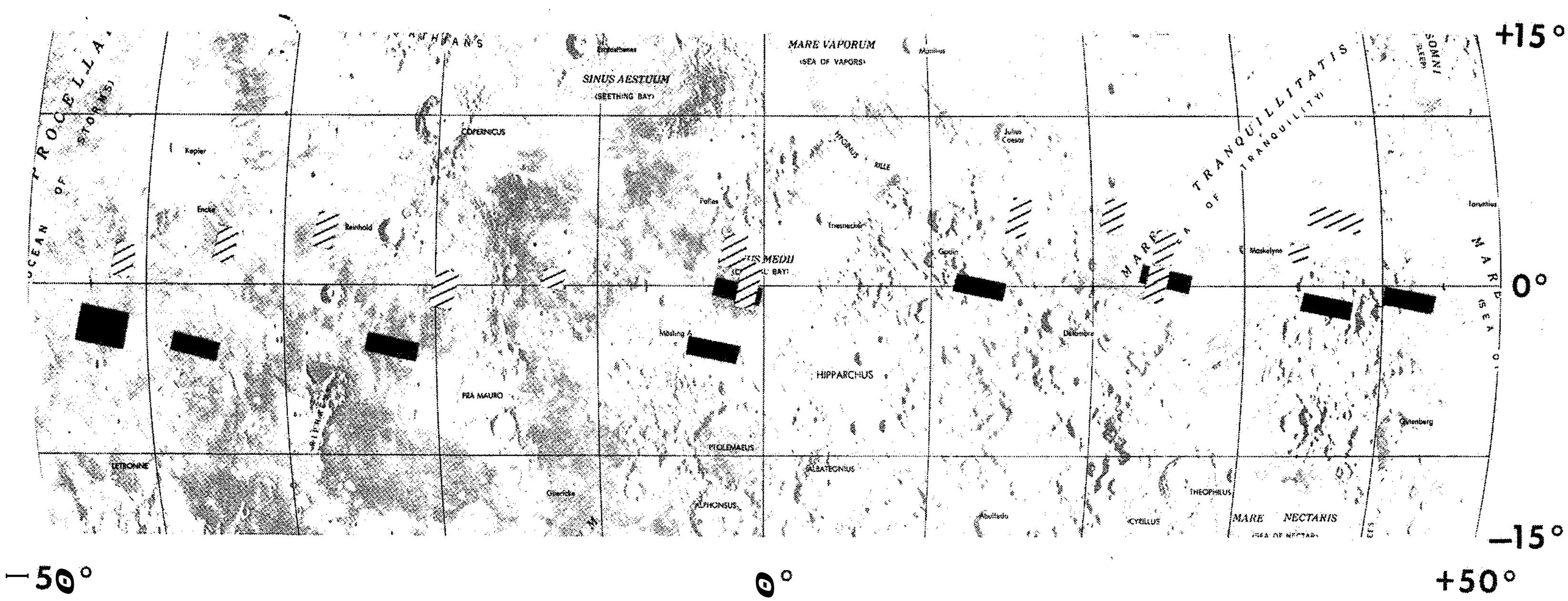
Orbiter Sites

It is expected that the landing sites employed for the first lunar landing mission will be selected from the entire set photographed in the Orbiter program. This viewgraph illustrates the sites which have already been photographed by Orbiter I and 11. It is from these that representative sites were chosen for this study.

# ORBITER SITES

'I' SITES

'II' SITES

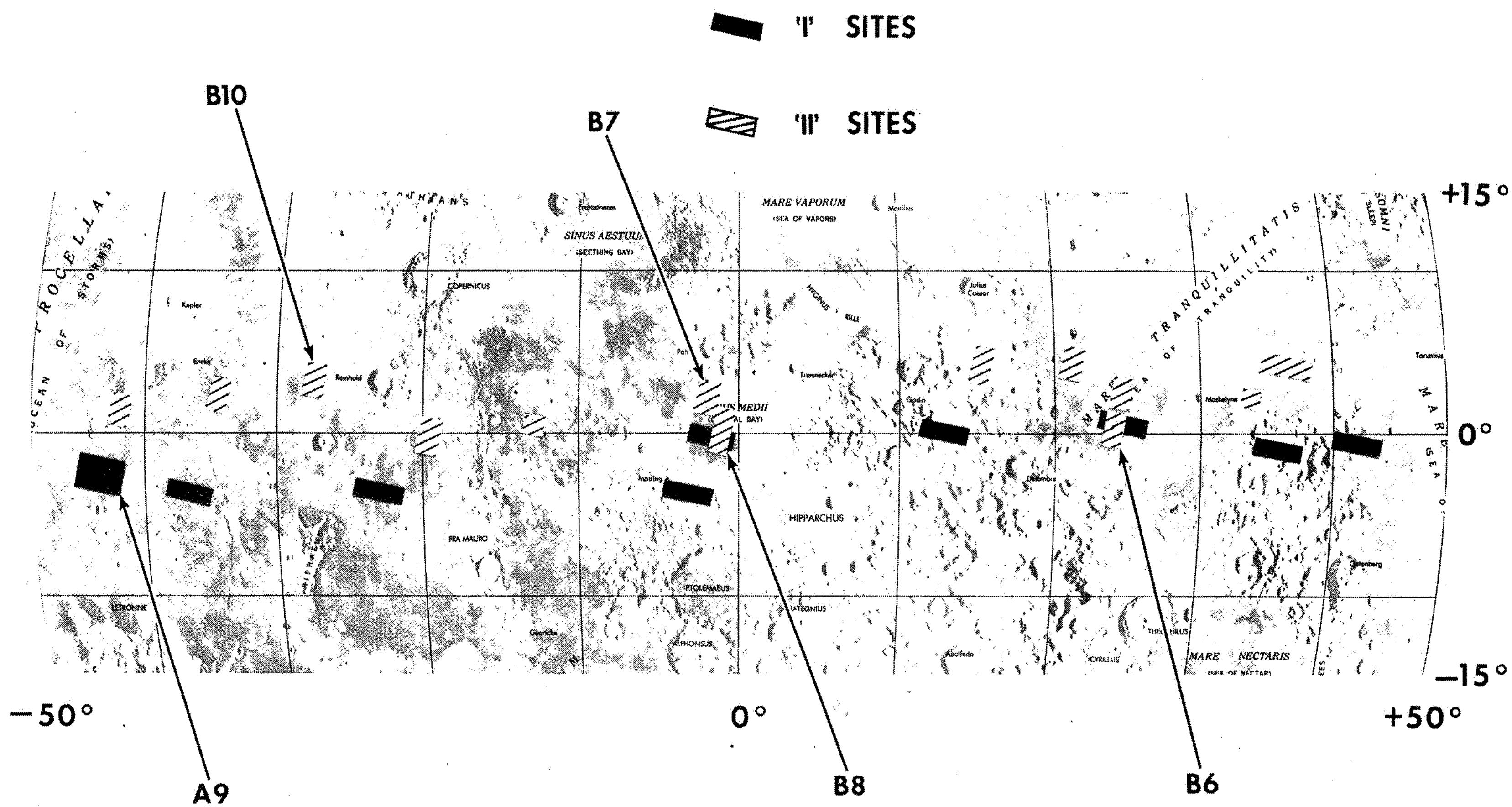


## Viewgraph 6

## Selected Orbiter Sites

The numbered sites shown on this viewgraph were selected as a representative set from the lunar Orbiter I and II sites in such a way as to acknowledge the lunar lighting constraint, launch recycle capabilities, and Service Module fuel capabilities. The five sites indicated here may be thought of as a northerly string consisting of B6, B8, B10 and a southerly string consisting of B6, B7, A9. Note that B6 is common to both strings. This does not cause any appreciable loss in generality because it tends to be true that less latitude spread is required in the east than in the west to control SM fuel requirements.

# ORBITER SITES



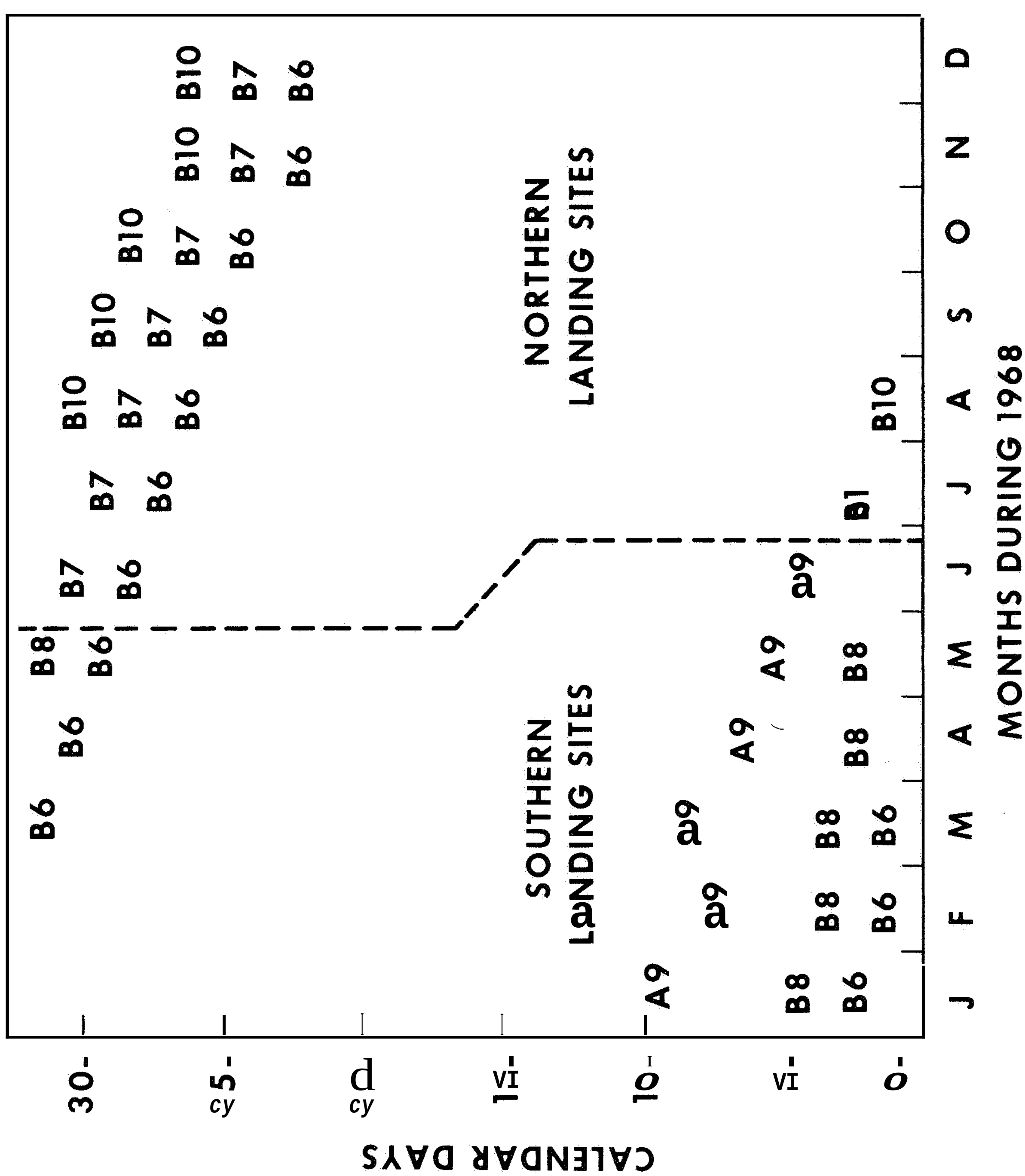
## Viewgraph 7

### Lunar Landing Mission Launch Opportunities

The launch opportunities during 1968 are illustrated on this viewgraph for the five sites shown in Viewgraph 6. The calendar day of launch is indicated by the vertical scale and the month by the horizontal. The day indicated by the site name (i.e., B6, A9) corresponds to a mission opportunity to that site for which all mission constraints are met.

The viewgraph indicates that southern landing sites are employed during the first six months and northern sites during the latter part of the year. As indicated in Viewgraph 4 this latitude selection is based upon the Service Module fuel requirements. All injections are over the "Pacific" area.

LUNAR LANDING MISSION LAUNCH OPPORTUNITIES



## Viewgraph 8

### Time Between Successive Launch Opportunities

The lunar landing sites for this study were selected to meet fuel requirements and the lunar lighting constraint. An additional consideration in the site selection process is the minimum allowable time between successive earth launch opportunities. Based on an assessment of launch facility capability, this time was restricted to a minimum of 48 hours between launch window centers. For this study the earth launch window was established by the range of launch azimuths 72 to 108 degrees, resulting in about a four hour period. This results in a minimum time from the end of one window to the start of the next usable window of approximately 44 hours. This viewgraph illustrates the time in hours from the center of a window (launch azimuth equal to 90°) to the center of the following window. Again, only Pacific injection opportunities are considered here.

# HOURS BETWEEN LAUNCH OPPORTUNITIES

(PACIFIC OPPORTUNITIES ONLY)

| | IDENTIFYING MONTH | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | DEC |
| RECYCLE FROM EAST SITE TO MIDDLE SITE | 51 | 51 | 51 | 50 | 48 | 48 | 48 | 48 | 48 | 51 | 52 | 52 | 51 |
| RECYCLE FROM MIDDLE SITE TO WEST SITE | 102 | 77 | 99 | 96 | 72 | 96 | 48 | 72 | 49 | 52 | 5[illegible] | 51 | 51 |

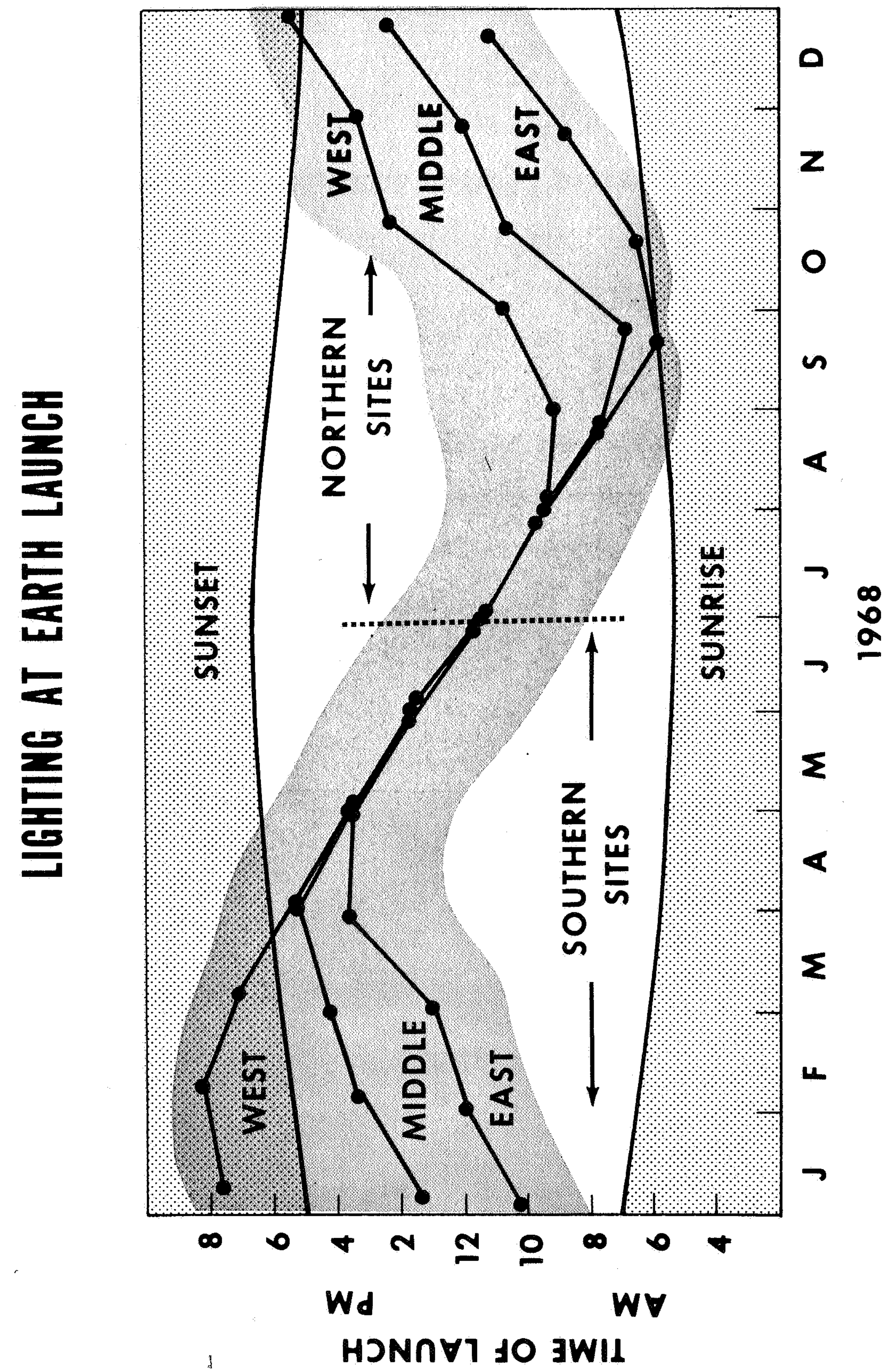
Viewgraph 9

## Lighting at Earth Launch

Utilizing the Pacific injection opportunity generally results in achieving daylight conditions at launch from KSC. This is a result of the lunar lighting constraint together with restricting landing sites to lie between $\pm 45°$ longitude. Another way of stating it is that the lunar-lighting constraint together with the longitude of the landing site establishes the approximate lighting conditions for all phases of the mission.

This figure shows launch times for each of the mission opportunities studied. The solid lines represent the variation in launch time throughout the year using a 90° launch azimuth only. The shaded area shows the variation which exists when the entire azimuth range from 72° to 108° is used.

For landing sites in the west, launches generally occur later in the day than for sites in the east. This effect is less pronounced during the summer months.


LIGHTING AT EARTH LAUNCH
SUNSET
SUNRISE
NORTHERN SITES
SOUTHERN SITES
WEST
MIDDLE
EAST
WEST
MIDDLE
EAST
TIME OF LAUNCH
PM
AM
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6
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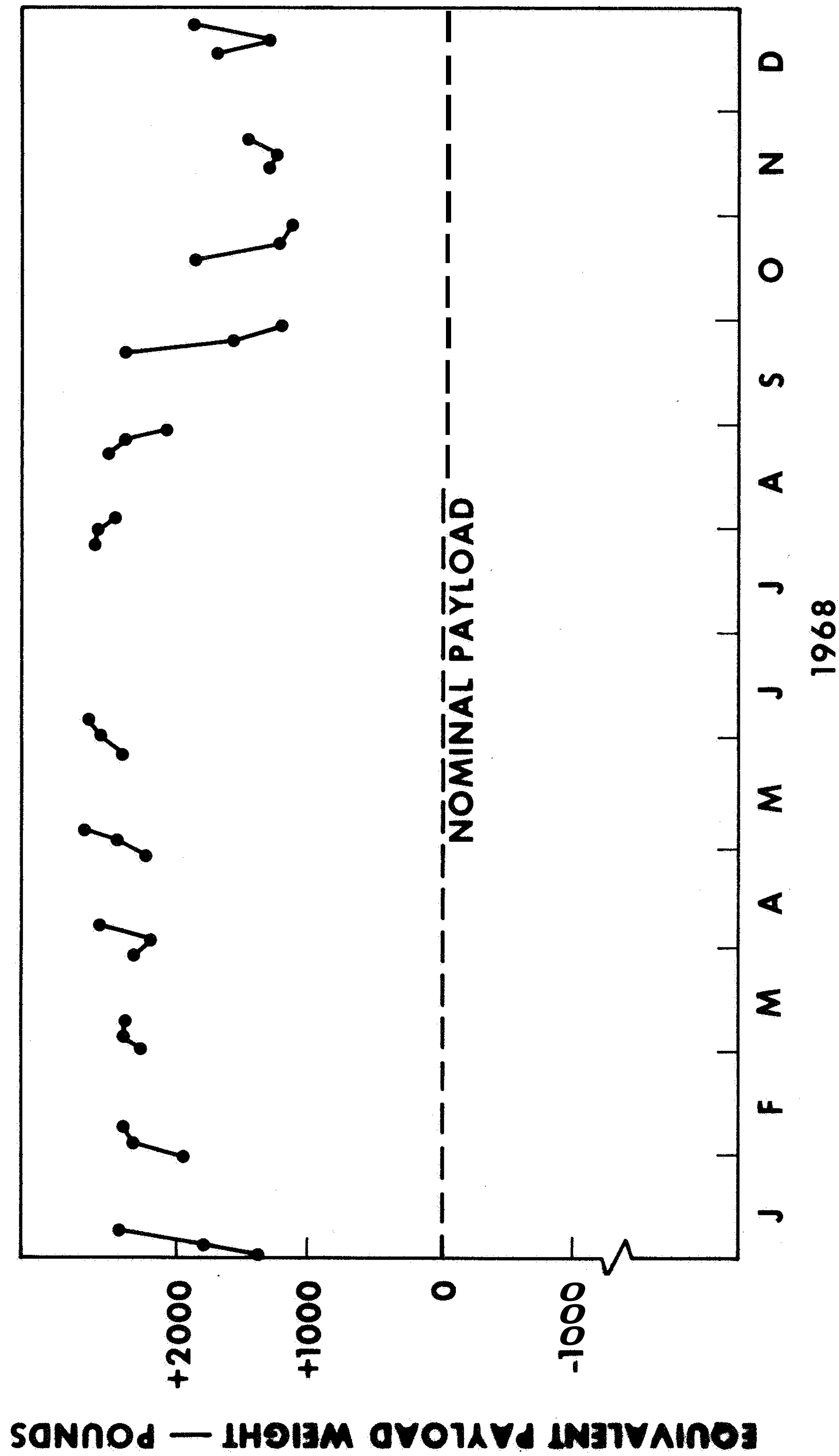
Viewgraph 10

Launch Vehicle Fuel Costs

The launch vehicle is required to be capable of delivering a specified payload on a free return trajectory with injection occurring on either of two consecutive earth orbits. Injection velocity requirements for a particular mission which are below the specified capability may be translated into equivalent payload excess. Viewgraph 10 depicts the launch vehicle payload excess available for the set of missions employed in this study. These results include the plane change cost incurred by using a split launch window. This viewgraph is intended to illustrate the yearly behavior of launch vehicle requirements and should not be thought of or predicting the payload capability for any particular mission opportunity.

TRANSLUNAR INJECTION REQUIREMENTS

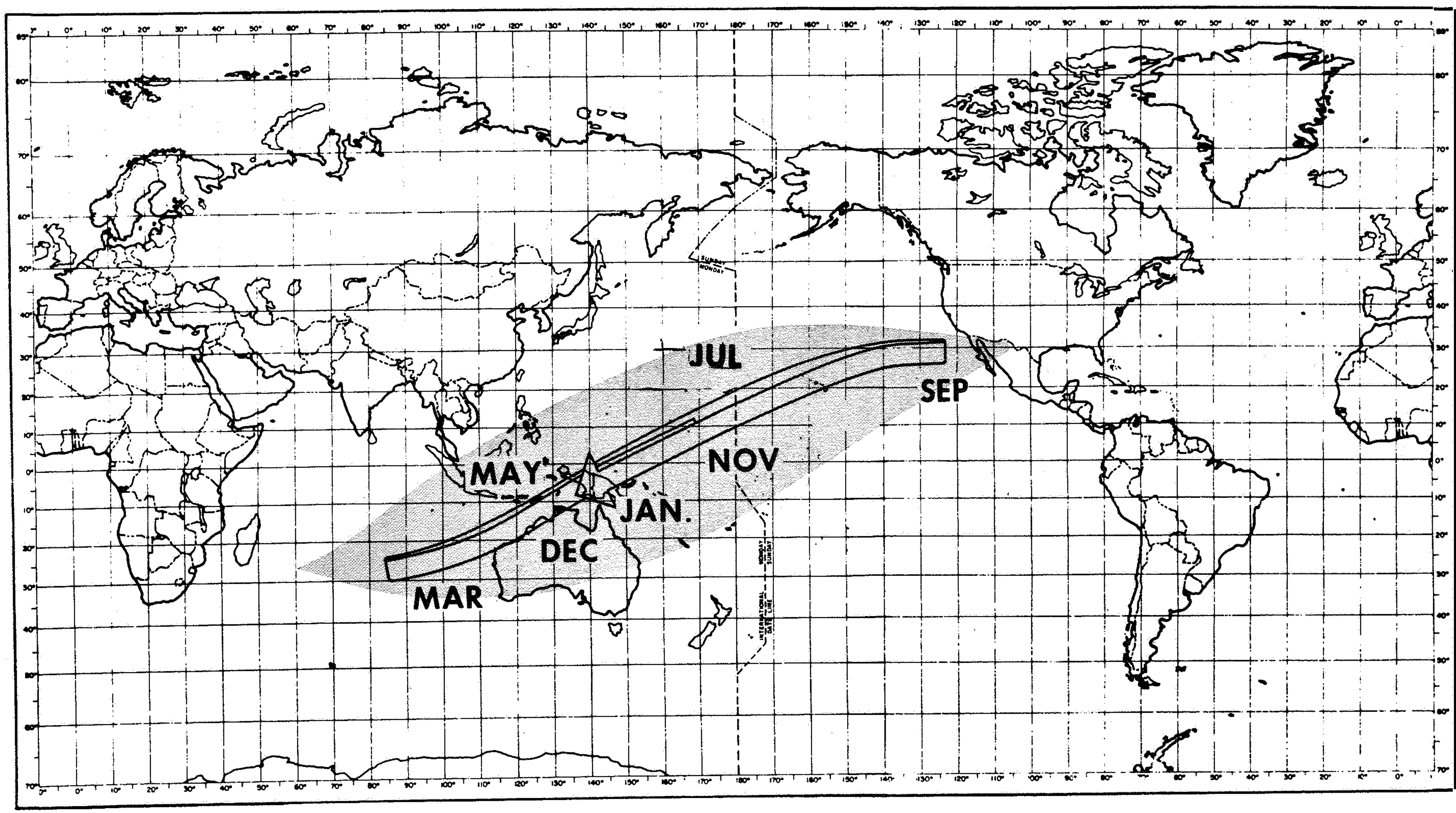


## Viewgraph 11

### Translunar Injection Locus

This figure shows the approximate locus of translunar injection initiation points for the Pacific opportunity. The looping arrow delineates the motion of the TLI initiation point through the year for a 90 degree launch azimuth with injection occurring on the second earth orbit (first opportunity). The shaded region shows the entire area mapped out by the initiation points when a 72 to 108 degree launch azimuth range and both second and third orbit injection opportunities are employed.

# TRANSLUNAR INJECTION



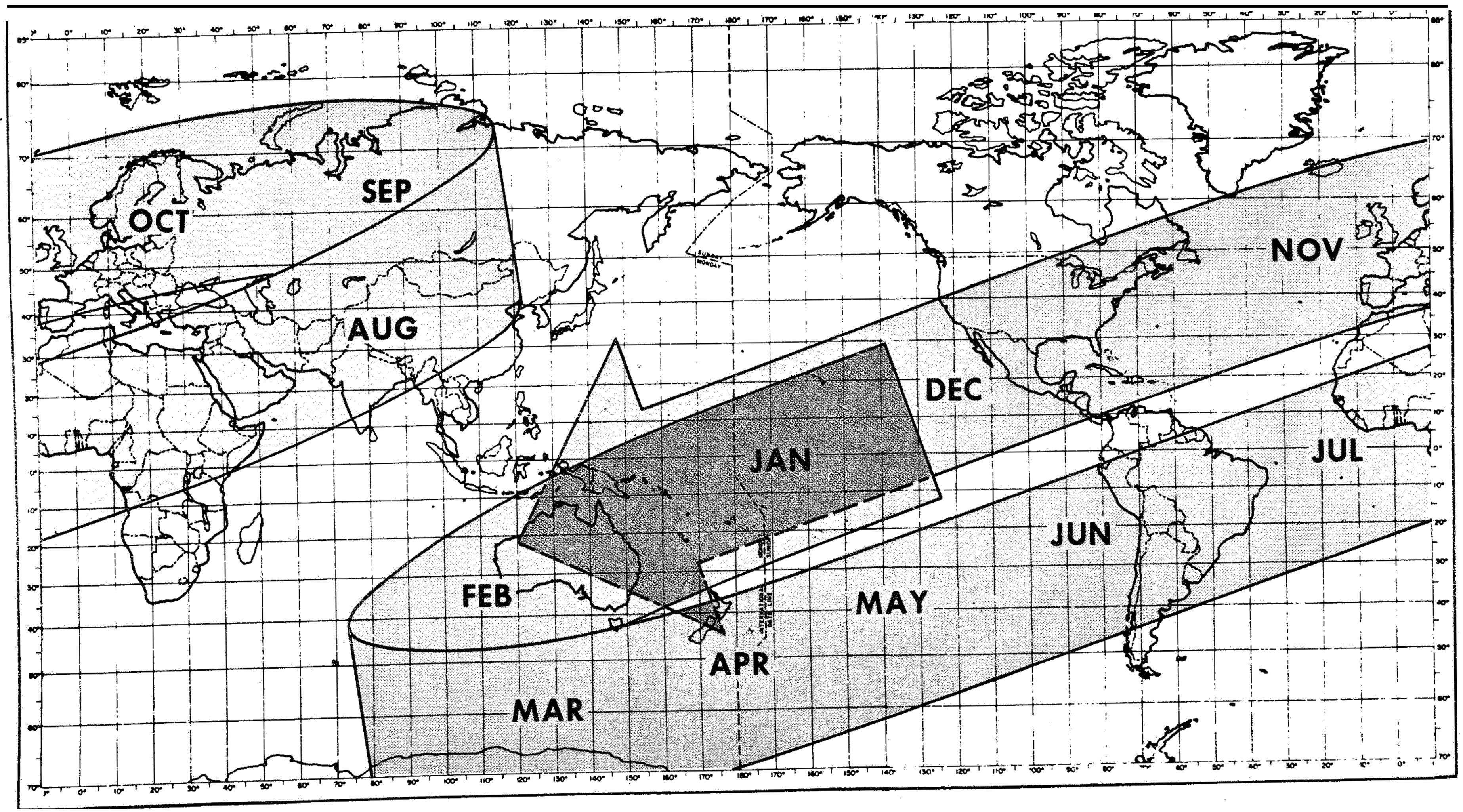
Viewgraph 12

Free Return Landing Point Locus

In designing a free return trajectory all that is required of the transearth leg is that it provide a posigrade reentry at a specified flight path angle. Under these conditions a wide variation in free return earth landing point location takes place throughout the year as well as from mission to mission.

This figure shows the general area where landing will occur on a month by month basis when no corrections are made to the nominal free return trajectory. Since transearth flight time can not be independently specified and still meet the free return constraint, the time of arrival at the Earth is uncontrolled. This results in wide landing point longitude variations as the Earth rotates under the return trajectory. Latitude variations result from the fact that landing occurs in the vicinity of the nadir of the Moon's position at the time of perilune passage.

# UNCORRECTED FREE RETURN LANDING



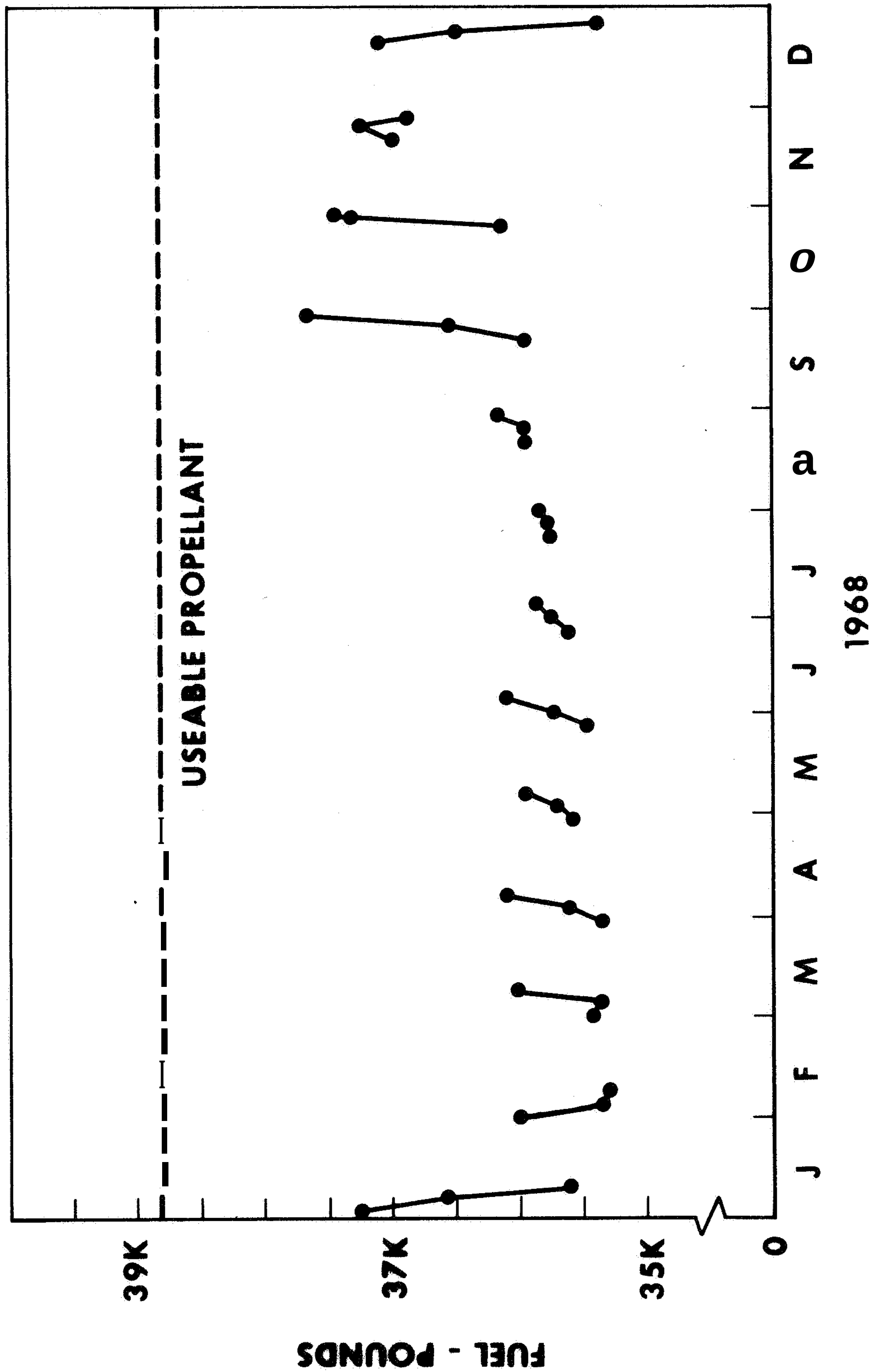
## Viewgraph 13

### Service Module Fuel Requirements

This viewgraph illustrates the variation of Service Module fuel costs through a yearly cycle. The Pacific Injection window was employed throughout.

To minimize Service Module fuel costs the southerly string is employed for the first half of the year and the northerly string during the second half. This graph includes the cost of midcourse corrections and LM rescue as provided by the ΔV budget. A two degree maximum LM out-of-plane angle was imposed in obtaining these data.

Since Service Module fuel is a sensitive function of lunar landing site position and certain mission constraints, these results should not be assumed to have meaning outside of the specific conditions of this study.



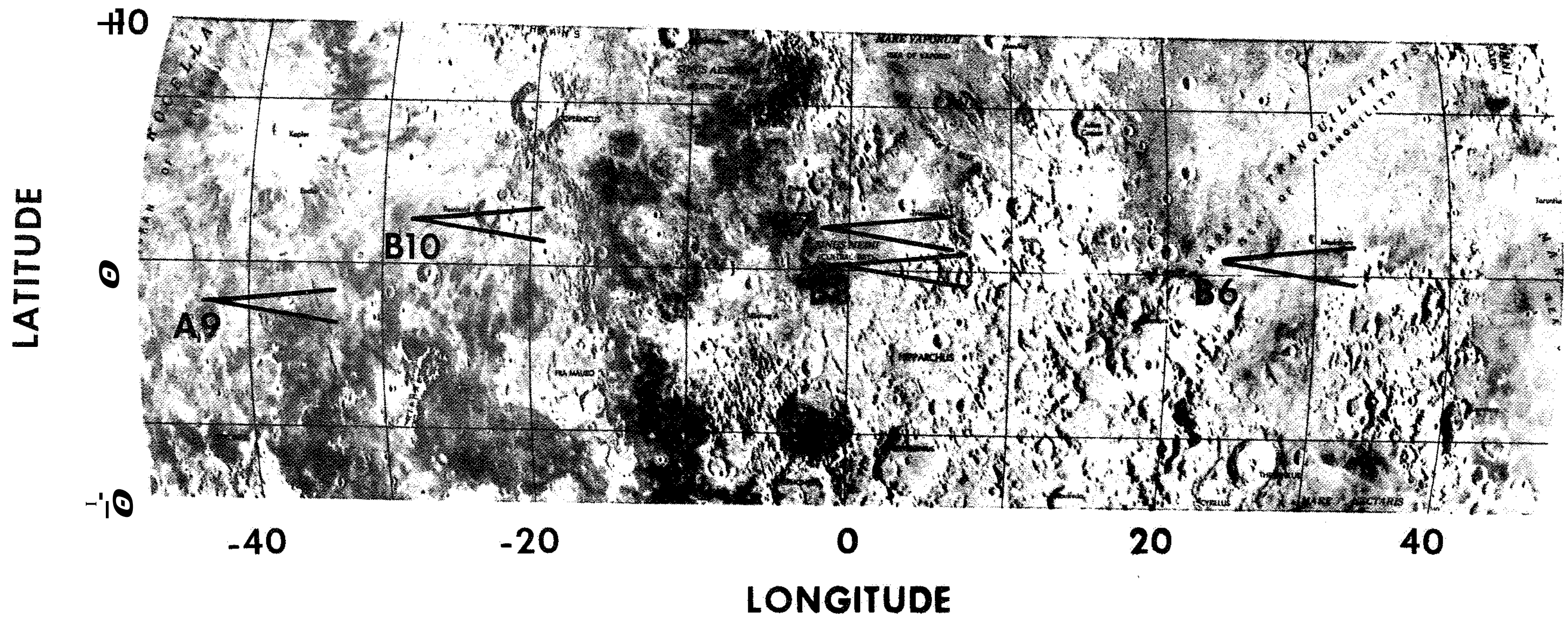

SERVICE MODULE FUEL

Viewgraph 14

## Lunar Approach Path Variations

The locus of parking orbit ground tracks through the year for a particular landing site defines the area covered by all possible approach paths to that site. In this analysis the LM out-of-plane angle was constrained to be 2 degrees or less throughout the entire contingency stay time. With this constraint and a defined surface stay time a range of possible approach paths is specified. Service module fuel can be optimized within this range of possible parking orbits. This viewgraph indicates approximately the approach path or flight azimuth range for the optimum trajectory at each of the selected sites for the entire year. The magnitude of this range as indicated by the pie shaped sectors is approximately ±5 degrees from due east.

# LUNAR APPROACH PA[redacted]H A A[redacted]ION



## Viewgraph 15

### Lighting at Lunar Landing

The lighting constraint for lunar landing is enforced to assure adequate visibility of the landing site. This figure shows the sun elevation at the time of landing for each of the missions studied. The present constraint is indicated in the figure by the dashed lines at 7 and 20 degrees.

It will be noted that in late November, the constraint is not met at all three sites chosen when launch occurs on the dates indicated in Viewgraph 7. The lighting conditions which exist when each of these launch dates are incremented by one day* are shown by the points connected by dashed lines at the top of the figure. Thus it is seen that the constraint cannot be met at the three sites chosen and still maintain the proper spacing between launch dates. This difficulty could be eliminated, in designing an actual sequence of missions, by selecting a slightly different longitude spacing between the landing sites.

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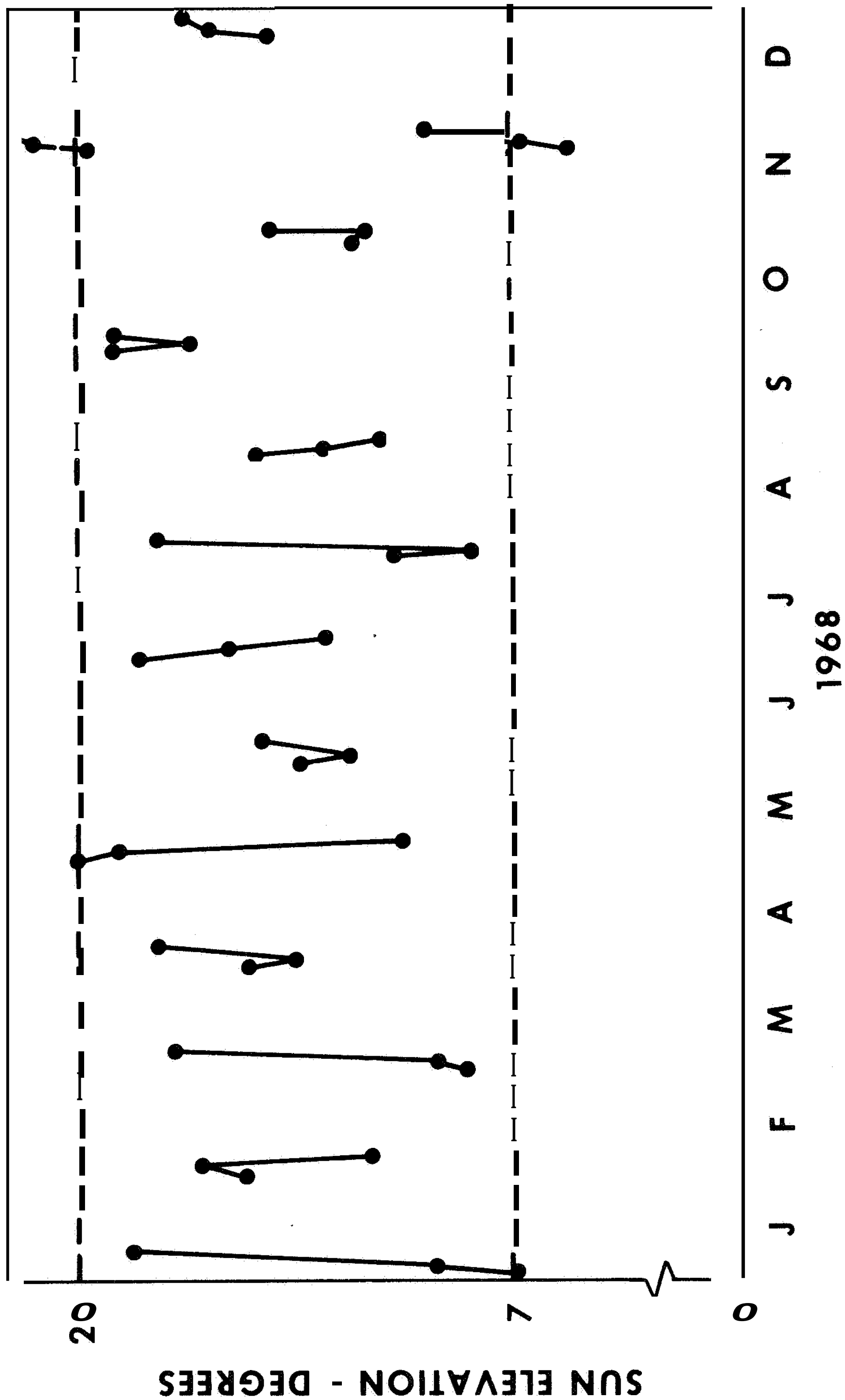
*Incrementing the first launch date requires incrementing the remaining two in order to maintain a minimum 48 hour spacing between them.

# LIGHTING AT LM LANDING

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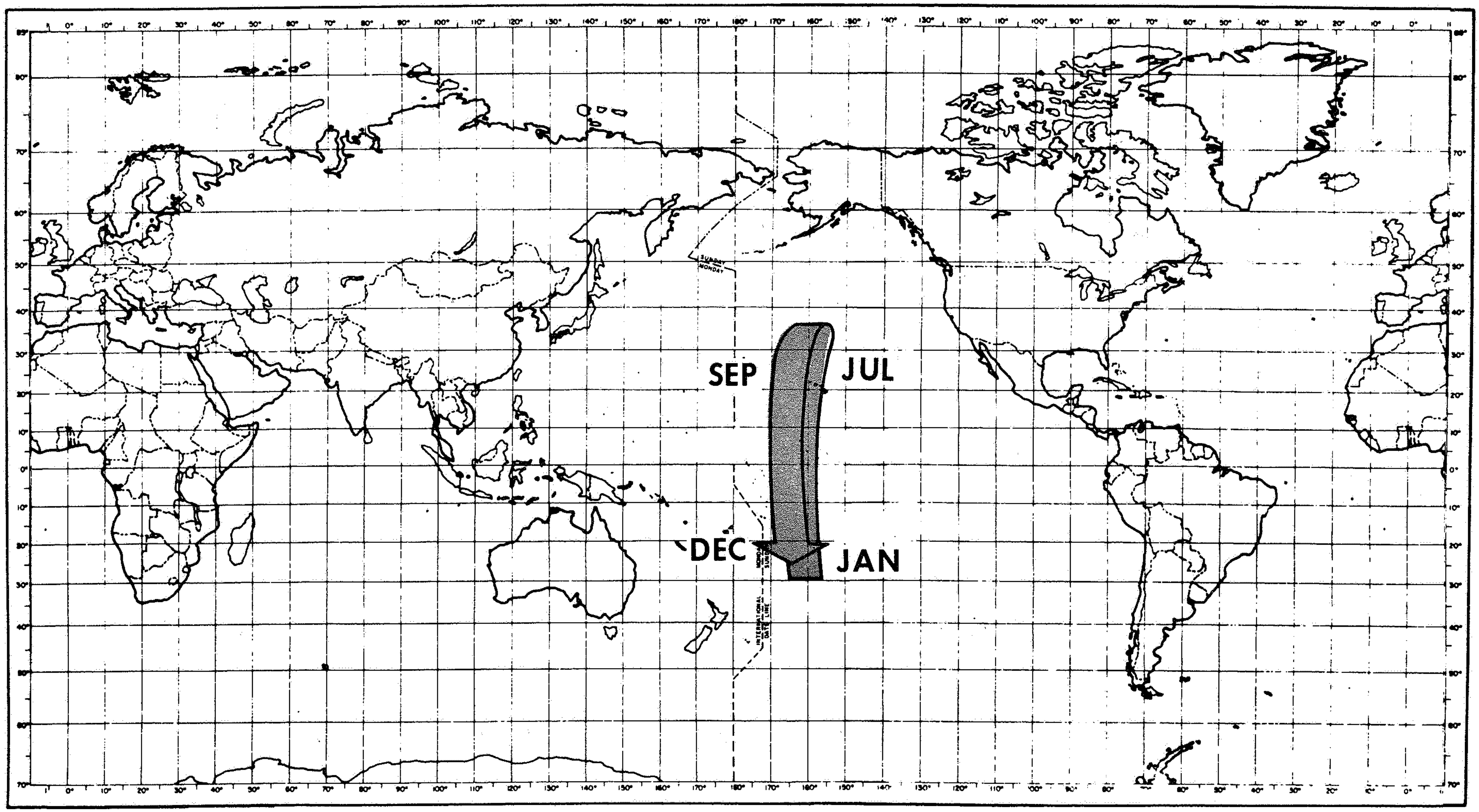
Viewgraph 16

Nominal Minimum Landing Point Locus

The nominal earth landing point is constrained to lie within a boundary specified by two latitude limits and two longitude limits. In this case the limits were ±35 degrees latitude and -170 to -150 degrees longitude. Landing at a more westerly longitude generally produces lower fuel costs since it allows longer return flight times. The motion of the landing point within the latitude boundary follows the motion of the nadir of the moons position vector at perilune passage.

# EARTH LANDING



Viewgraph 17

Lighting at Earth Landing

An examinition of the earth–sun–moon geometry shows that by setting the lighting constraint at lunar landing, the lighting at earth landing will also be established. In general a landing in the lunar morning will result in an earth landing in the morning. This viewgraph illustrates this and shows that as the terminator progresses around the moon (moving from east to west) it also must progress around the earth which leads to earth landings occurring later in the day for the westerly lunar landing sites. The lines marked "latest sunrise" and "earliest sunset" were derived for earth landing sites at the latitude extremes of the landing zone.

LIGHTING AT EARTH LANDING